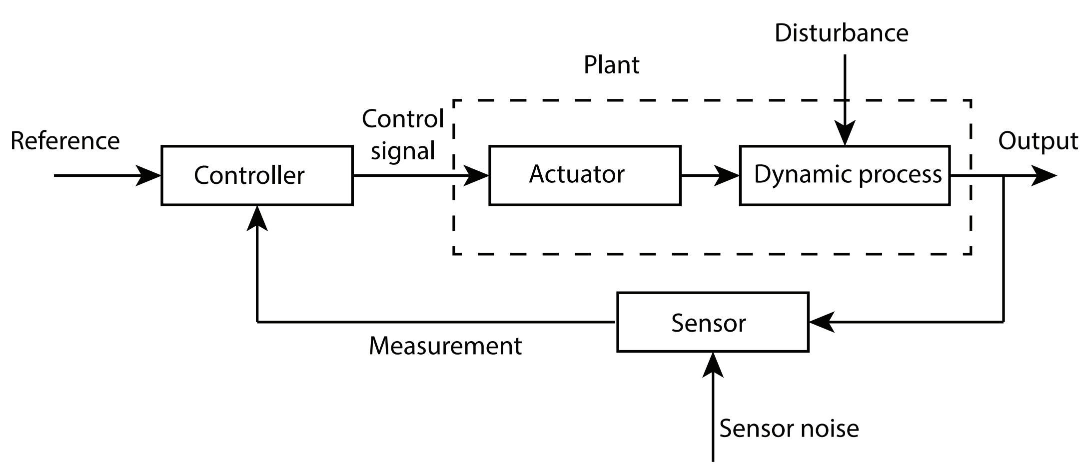
16.06 Principles of Automatic Control
Lecture 2

Reasons for using automatic control:

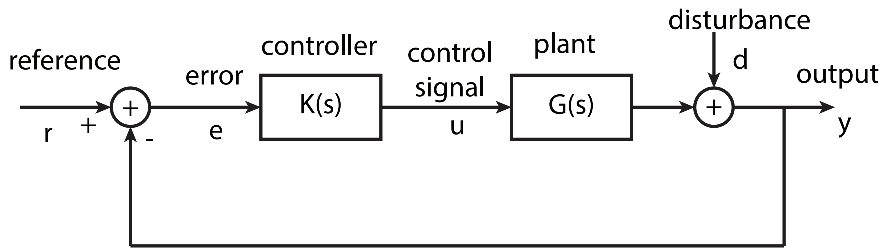
- Reduce workload
- Perform tasks people can't
- *Reduce the effects of disturbances*
- *Reduce the effects of plant variations*
- *Stabilize an unstable system*
- Improve the performance of a system (time response)
- *Improve the linearity of the system*

Requires closed-loop control!!

Components in a typical control system:



Typically, we are interested in cases where the plant and controller are linear and time-invariant, or can be modeled as such. Then we can represent components as transfer functions:

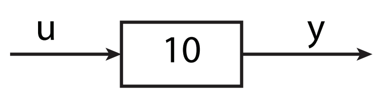


This block diagram form is extremely useful, and is used every day in this class.

Why are block diagrams so powerful?

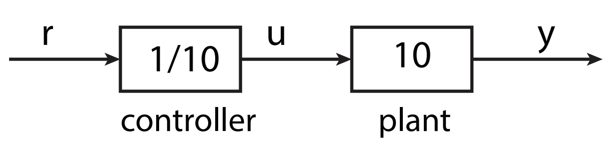
System is described by differential equations, but the transfer functions (Laplace transforms) reduce the differential equations to algebra. Yay!

Consider a very simple plant:

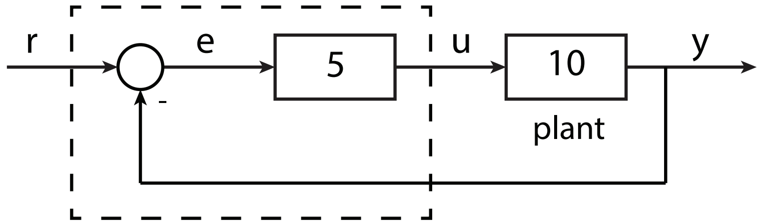


Suppose we want y to track reference signal r.

Could control by open-loop control



or by closed-loop control



Note that the control gain (5) is arbitrary - we'll figure out how to chose it later.

How well do these control systems work?

Look at transfer functions from r to y:

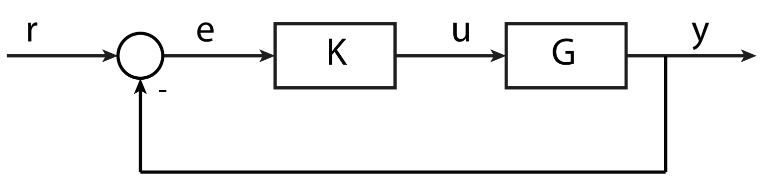
	Open Loop	Closed Loop
$\frac{y}{r}$	$\frac{1}{10} \cdot 10 = 1$	$\frac{5 \cdot 10}{1+5 \cdot 10} = \frac{50}{51} \approx 0.98$

We want $\frac{y}{r} = 1$, so at first glance, it looks like open-loop is better than closed-loop. However, consider what happens if it turns out our plant model was wrong (or changes), so that really $G = 15$. Then

	Open Loop	Closed Loop
$\frac{y}{r}$	$\frac{1}{10} \cdot 15 = 1.5$	$\frac{5 \cdot 15}{1+5 \cdot 15} = \frac{75}{76} \approx 0.9868$

That is, if the plant gain changes by 50%, the transfer function of the open-loop system will vary by 5-%. However, the transfer function of the closed-loop system will vary by only 0.66% (in this case).

More generally, for a typical unity-feedback control system:



The sensitivity of the closed-loop transfer function

$$H = \frac{KG}{1+KG} = \frac{y}{r}$$

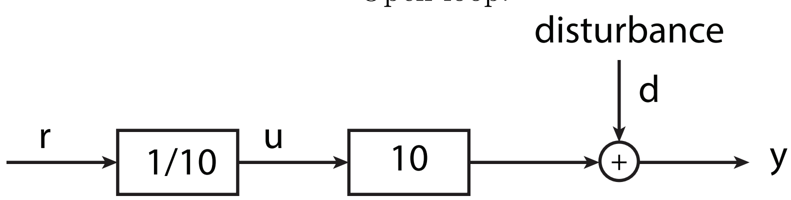
$$\text{is } S = \frac{1}{1+KG} = \frac{\text{\% change in H}}{\text{\% change in G}}$$

Big idea:

> High gain control loop reduces the sensitivity of the control system to variations in the plant.

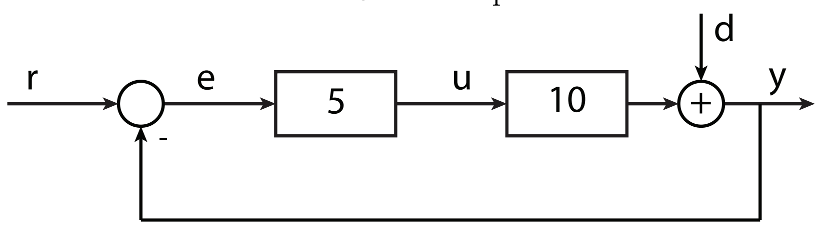
Now consider effects of a disturbance:

Open-loop:



$\frac{y}{d} = 1$

Closed-loop:



$$\frac{y}{d} = \frac{1}{1+KG} = \frac{1}{51} \approx 0.02$$

Big Idea:

> High-gain feedback control greatly reduces the effect of disturbances on the output of a control system.